Instructions to Inspectors

ON

Reinforced Concrete Construction

BY

GEO. P. CARVER

Lately Division Engineer
Florida East Coast Ry. Key West Ext.

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PREFACE.

In the preparation of this little book the write has tried to set forth in detail the duties of an in spector on reinforced concrete construction. Pa of these instructions are taken from Instructions t Inspectors on Reinforced Concrete arch construc tion prepared by the writer for use on the viaduc work of the Key West Extension of the Florid East Coast Railway, on which work the writer wa engaged as a division engineer in charge of th Long Key—Conch Key viaduct, which is two mile in length and composed of 180 semi-circular arche of 50 feet span constructed between two of th Florida Keys in a depth of water varying from 0 t 10 feet.

There are many of the instructions given fo this work that are applicable to building construc tion and practically any type of reinforced concret structure.

The instructions under the head of buildin construction were prepared by the writer for th use of the inspectors on the construction of th United Shoe Machinery Co. plant, a group of manu facturing buildings in Beverly, Mass. This plan is composed of about ten buildings all of reinforce concrete and is probably the largest plant of build ings of this construction in the world. The write was the engineer for the owners during the con struction of the plant.

It is hoped by the writer that these instruction based on the experience gained by him in this form of construction will be of direct value to engineer and contractors engaged in the inspection, super vision and construction of reinforced concret structures.

GEORGE P. CARVER,
Beverly, Mass.

February, 1907.

Reinforced Concrete Construction

Reinforced concrete construction requires rigid inspection, continuous and intelligent supervision.

Careful proportioning, mixing and compacting of the materials is necessary.

To omit or misplace the reinforcement will cause effective or even destructive results.

Inspection of Cement

(As recommended by the American Society for Testing Materials.)

All cement shall be inspected.

Cement may be inspected either at the place of manufacture or on the work.

In order to allow ample time for inspecting and testing, the cement should be stored in a suitable weather-tight building having the floor properly blocked or raised from the ground.

The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment.

Every facility shall be provided by the contractor, and a period of at least twelve days allowed for the inspection and necessary tests.

Cement shall be delivered in suitable packages, with the brand and name of manufacturer plainly marked thereon.

A bag of cement shall contain 94 pounds of cement net. Each barrel of Portland cement shall contain four bags, and each barrel of natural cement shall contain three bags of the above net weight.

Cement failing to meet the seven-day requirements may be held awaiting the results of the twenty-eight day tests before rejection.

The acceptance or rejection shall be based on the following requirements:

PORTLAND CEMENT.

Definition. This term is applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3 per cent. has been made subsequent to calcination.

SPECIFIC GRAVITY.

The specific gravity of the cement, thoroughly dried at 100 degrees C., shall be not less than 3.10.

FINENESS.

It shall leave by weight a residue of not more than 8 per cent. on the No. 100, and not more than 25 per cent. on the No. 200 sieve.

TIME OF SETTING.

It shall develop initial set in not less than thirty minutes, but must develop hard set in not less than one hour, nor more than ten hours.

TENSILE STRENGTH.

The minimum requirements for tensile strength for briquettes one inch square in section shall be within the following limits, and shall show no retrogression in strength within the periods specified:

Age.	NEAT CEMENT.	Strength
24 hours in moist air		150-200 lbs
7 days (1 day in moist air, 6 days in water)		450-550 lbs
28 days (1 day in moist air, 27 days in water)		550-650 lbs
	ONE PART CEMENT, THREE PARTS SAND.	
7 days (1 day in moist air, 6 days in water)		150-200 lbs
28 days (1 day in moist air, 27 days in water)		200-300 lbs

CONSTANCY OF VOLUME.

Pats of neat cement about three inches in diameter, one-half inch thick at the centre, and tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(a) A pat is then kept in air at normal temperature and observed at intervals for at least 28 days.

(b) Another pat is kept in water maintained as near 70 degrees F. as practicable, and observed at intervals for at least 28 days.

(c) A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

These pats, to satisfactorily pass the requirements, shall remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

SULPHURIC ACID AND MAGNESIA.

The cement shall not contain more than 1.75 per cent, of anhydrous sulphuric acid (SO_3), nor more than 4 per cent. of magnesia (MgO).

INSTRUCTIONS

IN GENERAL.

Inspectors will be required to become familiar with and carefully follow out the following instructions regarding inspection and see that the work is carried out in strict accordance with same. An inspector will be required to be on the work during the setting of forms, placing of reinforcement and the mixing and placing of concrete. He will represent the Engineer-in-Charge, and will be held responsible for the correct performance of the work assigned to him. He will, in a general way, carefully and continuously watch the progress of the work, making a record of the amount of work done each day and the manner in which it is done.

He will be required to become thoroughly familiar with the plans of the work which he is inspecting, that he may intelligently perform the duties intrusted to him. He will be required to fill in a daily report sheet, printed forms being furnished for this purpose, giving the location of the work, the amount of work done, the number of batches mixed and placed, the proportions used, the arrival of material and all such other information as will assist in making a concise and accurate record of the progress and cost of the whole or any part of the work.

A book will be furnished the inspector, in which a record will be kept of the progress of the work, and the following information should be recorded: Date; time of day of each entry; day or night work; number of men; foreman; condition of forms; condition of steel; number and location of lights (if night work)

and if properly lighted; number, time and location of test cubes taken; rate of mixing; size and number of batches; proportions of mixture; arrival of material; kind, amount, etc.

Inspectors will be required to fill in several daily report blanks that will be furnished.

Inspectors will receive further written instructions from the Engineer-in-Charge from time to time, and will attach same to these instructions and will consider them a part of same. He will see that the following specific instructions are carried out:

FORMS.

That the forms are properly set up and braced.

That the concrete face of the forms are given a coat of oil, applied with a brush.

That an excess of oil is not used.

That the forms are cleaned at each setting and recoated with oil.

That the forms are correctly placed, allowing the depth, width and batter called for on the plans.

That the inside of the forms is free from debris (shavings, sawdust, blocks of wood, etc.) just previous to pouring.

That the forms are properly held together with No. wire or rods of suitable dimensions, and temporary spacing pieces are used and removed when the concrete reaches their height.

That the joints formed by the edges of the lagging are tight, so that grout will not escape, and that such defects are remedied by the use of plaster of paris, calking, strips of wood or other suitable approved methods.

That in Bridge Construction the arch centers are lowered sufficiently to allow the arch ring to assume its permanent set before spandrel walls are poured, in this manner reducing the possibilities of cracks occurring in spandrel walls because of possible excessive settlement in crown of arch ring.

STEEL REINFORCEMENT.

That the correct number and size of reinforcing bars are used, and that they are placed as shown on plan.

That all steel used is free from loose or scaly rust. (A thin film of rust will not cause the rejection of a bar.)

That bars covered with loose, scaly rust are cleaned with a stiff wire brush or given a pickling bath of a sulphuric acid solution (consisting of 1 part acid to 6 parts of water) and dipped in clean water.

That the intersection of the rods are wound with a length of No. 18 wire in a sufficient number of places so that the whole steel reinforcement will be fabricated sufficiently strong and rigid to withstand the placing of concrete about the steel and without disturbing the position of same.

That the bars are speced the proper distance apart and away from the face of the form work and are secured properly and held in that position in such manner that they will not be disturbed by the placing of concrete.

That in bridge construction all protruding bars from piers and arches to which other bars are to be spliced and which will be exposed to the action of the weather for an indefinite period are protected from rusting by a coat of thin, neat cement grout.

That the position of the steel is not disturbed during pouring.

MIXING.

Inspectors will be required to carefully and continuously watch the mixing of the concrete and the desired result must be obtained with either hand or machine mixing.

Machine Mixing.

He will see that a power, batch mixer of an approved type is used, constructed and operated in such a manner as to allow proper feeding of the materials, the thorough mixing of the component parts, perfect regulation in the admission of water and proper discharging.

That the required number of turns for the consistency used is determined by trial and this shall constitute the minimum number of turns allowed before discharging.

That the entire batch is discharged each time.

That the concrete shall not be allowed to drop any considerable distance when discharging, having a tendency to separate the ingredients.

That the mixer is flushed with water and thoroughly cleaned before being allowed to stand idle.

That the concrete is delivered to point of disposal in water tight carriers.

Hand Mixing.

That the receptacles used for measuring sand and broken stone are of the correct dimensions.

That the sand and cement are mixed dry until of a uniform color before adding water.

That the proper amount of water required for the consistency used is determined by trial and this amount used.

That the stone is thoroughly wetted before being incorporated with mortar.

That the stone is spread in a layer of uniform thickness over mortar and the whole turned a sufficient number of times so that all grains of sand and each particle of stone shall be coated and a uniformly mixed concrete free from streaks is obtained.

PLACING CONCRETE.

The inspector will see that the specified proportions of material are used in mixing the concrete.

That the concrete is of the proper consistency.

That an accurate account is kept of the number of batches mixed, the same to be recorded on a printed card which will be furnished for that purpose.

That these batch record cards are preserved and filed for future reference.

That in placing the concrete the same will be done in a careful manner and precautions taken not to allow the concrete bucket to come in contact with the form work.

That care is taken not to jar the form work until the concrete work is hardened.

That in making a bond between old and new work care is taken to thoroughly clean the surface of old concrete (preferably by a jet of steam), and that a thin layer of a 1 to 1 grout is spread to assist in making a good bond.

That the surface of the concrete which is to be bonded to other concrete is left in a rough condition, either by spreading a layer of broken stone over the same, ramming half the depth of the stone into the green concrete and leaving the upper half of the stone protruding, or by setting in strips of wood, which when removed, will form a groove and assist in making a good bond.

That in bonding the spandrel wall with the arch ring, a groove or ridge is formed on arch rings running under and with spandrel wall to prevent water from center filling to run through and down the face of arch ring discoloring same.

That in placing dry concrete the same is thoroughly compacted with suitable approved iron tamps.

That in pouring wet concrete the same is thoroughly spaded, rodded and worked with suitable tools sufficiently to cause all air bubbles to escape, to work grout to face of form work filling all voids and showing a smooth, well mixed concrete free from voids when forms are removed.

That a fine mixture of 1 to 3 is deposited around and among the bars, and that it is thoroughly worked in and around the bars in such a manner that the steel will be completely surrounded, embedded and covered.

That all concrete is deposited in forms within 30 minutes after leaving mixer.

That all exposed surfaces of concrete are kept continually wet for a period of 10 days after the removal of forms.

Care should be taken not to allow the first concrete placed to appreciably stiffen or set before the remaining concrete is placed. The remedy for this is to occasionally, as often as is necessary, add a little more concrete to that already placed over all exposed surfaces.

Great attention is necessary to make each section (pier, arch ring or spandrel wall) monolithic in height, length and width. Only when circumstances render it practically unavoidable may the work be stopped before the entire section is completed.

IN BUILDING CONSTRUCTION.

The inspector is required to see that the following is adhered to:

1. The right size and number of rods used.

2. The rods are placed as designed.

3. The U bars are placed correctly, and right size and number used.

4. Pouring concrete does not disturb position of steel.

5. The bucket is lowered lightly on floor.

6. The bolts in bottom of beams and girders for shaft hangers are correct for position per plan.

7. No shavings cling to steel coil in columns.

8. No work is done in the dark.

9. Concrete is properly mixed.

10. Concrete gets under rods and around coiled couplings, etc.

11. Wearing surface is protected by boards until set.

12. Wearing surface is laid to level grade.

13. If forms are oiled see that there is no excess of oil used.

14. Concrete is moulded within thirty minutes after leaving mixer.

15. In mixing concrete in cold weather, aggregates are heated.

16. Wearing surface is laid before base has initial set.

17. The expansion joints are properly placed.

18. After the base of floor is poured it is protected from heat or cold.

19. Concrete in bay is carried to center of girder. Bay must be completed.

20. Coil couplings are properly located and properly installed.

21. All steel is clean, and entirely free from all dirt and loose rust.

22. In joining new work on old, hose is played on old where new work will join on, and wash with cement grout.

23. All forms are well swept and free from debris before pouring concrete into same.

24. Pouring beams, girders, columns, etc., is a continuous, or as nearly so as possible, operation until same is completed.

25. Concrete is kept wet continually for a period of two weeks after being poured.

26. Fires are kept burning in salamanders on floor below whenever concrete is poured in cold weather.

27. Before finished floor is laid the surface of concrete which is to receive the wearing surface is properly compacted or tamped.

28. Concrete is properly "cut" in all beams, girders and columns before the base of floor is laid.

29. No aggregates other than called for in the specifications are moulded in the forms.

30. Concrete should be well sliced and puddled into all girders, beams, columns, etc.

31. Notes should be made of any cracks that may appear in concrete due to forms expanding, contracting or settling. Note condition of forms before concrete is poured.

PROPORTIONING THE CONCRETE.

The proportion of concrete used depends upon the class of work for which it is intended and varies between a 1—1½—3 and a 1—4—8 mixture. For light columns and thin roof beams and for ornamental work a 1—1½—3 mixture is suitable.

For beams, floor slabs and columns a 1—2—4 or a 1—2—5 mixture is suitable.

For non-bearing walls, reinforced piers and footings a 1—3—5 mixture is suitable.

For mass concrete, a 1—3—6 to 1—4—8 mixture is used.

What might be determined as an ideal concrete is where the vol. of cement slightly exceeds the voids in the sand and the vol. of mortar slightly exceeds the voids in the stone. If this were followed out by tests and the actual voids in the sand and stone determined it would probably develop that a 1—3—6 mixture would be suitable where a 1—2—4 mixture was being used and would effect a considerable saving.

If sand is coarse and of graded sized grains and the broken stone is proportioned by the use of sizes varying from 1½ in. to ¼ in. so that the voids would be reduced to say 20 per cent., a very dense and suitable concrete could be obtained with a 1—3—6 mixture and equal in every way to a 1—2—4 mixture made up of aggregates the voids of which are not determined.

For finishing floors a 1—to—1 to a 1—to—2 mixture of sand and cement is used.

COST OF CONCRETE.

Assume 1—2—4 mixture.

Cement $2.00 per bbl.
Sand $1.00 per cu. yd.
Stone $1.50 per cu. yd.
} Delivered on the site of the work.

1 bbl. cement—3.8 cft. Sand 30 per cent. voids. Stone 45 per cent void.

1 cu. yd. concrete requires.

1.54 bbls. cement at 2.00	$3.08	
11.7 cft. sand at 1.00 c. y	.43	1-3
23.4 cft. stone at 1.50 c. y	0.86	2-3
Cost of materials per c. y	$4.38	

Cost of mixing and handling depends on facilities for getting material to mixer and away from mixer. The actual cost of mixing with machine is very small. With good supervision and best layout of plant the cost per cubic yard should average about $1.50 for handling, mixing and placing concrete in building construction. This gives a total of $5.88 per cu. yd. for a 1—2—4 mixture of concrete exclusive of formwork and reinforcement with material at the above prices. The cost per cu. yd. of any mixture used can be determined in this manner knowing the cost of each kind of material delivered on the work.

COST OF BUILDING.

Factory buildings of reinforced concrete, including windows, doors and roofing, cost from 8 to 16 cents per cubic foot of contents.

COST OF REINFORCEMENT.

The amount and cost of reinforcement greatly depends upon the system used which varies in amount and grade of steel used. The deformed bars and other patented forms of reinforcement necessarily increase the cost of manufacture over plain and commercial shapes which when used usually require a larger percentage to attain the same requirement owing to its lower tensile strength and bond.

In estimating the cost of the reinforcement required with any degree of accuracy it is necessary to determine the exact amount of steel required as shown on plans and with a price per ton, determine exactly the entire cost of reinforcement for the building. The price for steel for this purpose varies from 2 cents to 5 cents per lb.

Floors require from 2½ to 6 lbs. of reinforcement according to the floor load carried, including slabs, beams, girders, columns, lintels and footings.

COST OF FORMWORK.

The cost of formwork varies with the class of work and the number of times it can be used.

The formwork on a small building costs more per cubic yard of concrete placed than the formwork in a large building, where it can be re-used as many as four times with a very small percentage of loss or waste, because of the similarity of dimensions in the various structural members.

Formwork may cost from fifty cents to two dollars per cubic yard of concrete placed, depending on the volume of concrete the forms retain and the simplicity or irregularity of same, and the amount of bracing required to hold same in place.

STRIPPING FORMWORK.

To determine if concrete has sufficiently hardened to allow removal of forms several methods are adopted. Probably the best and most scientific is to take test cubes on each section of floor poured and set a minimum compressive strength that it must attain before removal of forms, and when the cubes show the strength by test it is safe to remove formwork on the section from which cube was taken. Another method is to attempt to drive a 20 penny wire nail into the concrete and if nail bends before a penetration of 2 inches is reached, under medium heavy blows with a carpenter's ordinary claw hammer, it is safe to remove forms.

It is usually safe to remove forms from non-bearing walls, etc., in five days from May to October, and eight days from October to May. For columns and floors, eight to fifteen days from May to October, and ten to twenty days from October to May.

WATERPROOF CONCRETE.

It has been determined in the construction of reservoirs, etc., that an admixture of about ten per cent. of hydrated lime to the amount of cement used will make a rich mixture of concrete waterproof. There are also a number of patented mixtures, which when added to the concrete during mixing or washed on the surface of the concrete after the removal of forms, have a waterproofing effect.

When it is desired to obtain a concrete that is impervious to water, a rich mixture of not more than 1—2—4 should be used, the broken stone or screened graved to be clean and range in size from ¾ in. to ¼ in. in diameter.

It has been determined that concrete reaches its maximum strength in about three years. To retard the setting of cement, which is desirable at times in order that it will attain greater strength ultimately, add three pounds slacked lime and a solution of common salt and water, using two pounds to the gallon, and add one gallon of the solution to each barrel of cement used.

FORMULAS

For the Design of Reinforced Concrete Beams.

Mb=Ultimate bending moment in inch lbs.

$\frac{wl^2}{8}$=Mb simple beam uniformily loaded.

$\frac{wl^2}{10}$=Mb continuous beam uniformily loaded.

w=weight on beam per lineal ft.

l=length of beam from cen. to cen. of supports.

Mr=Mb.

$Mr=90\ bd^2$.

b=width of beam.

d=depth of beam.

With steel of an elastic limit of 54000 lbs. use an area of 75% bd.

With steel of an elastic limit of 35000 lbs. use 1.00 to 1.25% bd.

TABLE OF SAFE LOADS FOR REINFORCED CONCRETE COLUMNS.

Size of Col.	Stress per Sq. Inch		
	300 lbs.	400 lbs.	500 lbs.
8x8	19,200	25,600	32,000
10x10	30,000	40,000	50,000
12x12	43,200	57,600	72,000
14x14	58,800	78,400	98,000
16x16	76,800	102,400	128,000
18x18	97,200	129,600	162,000
20x20	120,000	160,000	200,000
22x22	145,200	193,600	242,000
24x24	172,800	230,400	288,000
26x26	202,800	270,400	338,000
28x28	235,200	313,600	392,000
30x30	270,000	360,000	450,000
32x32	307,200	409,600	512,000
34x34	346,800	462,400	578,000
36x36	388,800	518,400	648,000

Steel		Stress per Sq. Inch		
Rods	Area	4,500	6,000	7,500
4— ½"	0.785	3,532	4,710	5,887
4— ⅝"	1.227	5,521	7,362	9,202
4— ¾"	1.767	7,951	10,602	13,252
4— ⅞"	2.405	9,202	12,270	15,337
4—1"	3.141	14,134	18,846	23,557
4—1 ⅛"	3.976	17,892	23,856	29,820
4—1 ¼"	4.908	22,086	29,448	36,810

Materials Required for 1 Cubic Yard of Concrete with ¾ Inch Stone

Proportions of Mixture			Required for 1 cu. yd.		
Cement	Sand	Stone	Cement bbls.	Sand c. yds.	Stone c. yds.
1	1.5	3	1.85	0.42	0.84
1	2.0	4	1.46	0.44	0.89
1	2.0	5	1.27	0.39	0.97
1	2.5	5	1.19	0.46	0.91
1	3.0	5	1.11	0.51	0.85
1	3.0	6	1.01	0.46	0.92
1	4.0	8	0.77	0.47	0.93

Concrete with 2½ Inch Stone and under

Proportions of Mixture			Required for 1 cu. yd		
Cement	Sand	Stone	Cement bbls.	Sand c. yds.	Stone c. yds.
1	1.5	3	1.90	0.43	0.87
1	2.0	4	1.48	0.45	0.90
1	2.0	5	1.29	0.39	0.98
1	2.5	5	1.21	0.46	0.92
1	3.0	5	1.14	0.52	0.87
1	3.0	6	1.02	0.47	0.93
1	4.0	8	0.78	0.48	0.95

Materials Required for 1 Cu. Yd. Mortar

Parts of Sand mixed with one part Cement

	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
Bbls. Cement	4.70	3.70	3.04	2.58	2.21	1.94	1.72	1.41
Cu. yds. Sand	0.71	0.84	0.92	0.98	1.01	1.03	1.05	1.08

CONCRETE FOOTINGS.

Plain concrete footings for earth pressure of

1 ton per sq. ft. height = 0.5 (base—width col.)
2 tons " " " " = 0.75 (base—width col.)
3 " " " " " = 0.90 (base—width col.)
4 " " " " " = base—width col.)

Step footings in courses

Reinforced concrete footings for earth pressure of

1 ton per sq. ft. height = 0.175 (base—width col.)
2 tons " " " " = 0.35 (base—width col.)
3 " " " " " = 0.525 (base—width col.)
4 " " " " " = 0.70 (base—width col.)

For reinforcement use rods of a diameter equal to base÷100 spaced 10 times their diameter apart and one-tenth of height from bottom of footing.

To Determine Quantity of Materials Required for a Known Amount of Concrete

Materials required for 1000 cu. yds. of 1—2—4 concrete 1 bbl. cement 3.8 cu. ft. sand 30% voids, stone 45% voids.

1 bbl. cement	3 8 cu. ft.	3.80 c.f.
2 bbls. sand	7.6 c.f. 30% voids	5.32 c.t.
4 bbls. stone	15.2 c.f. 45% voids	8.36 c.f.
loose material	26.6 c.f.	in place 17.48 c.f.

1 bbl. cement produces 17.48 c.f. concrete.

1 cu. yd. concrete requires (27.0÷17.48) = 1.54 bl. cement.

7.6 c.f. sand produces 17.48 c.f. concrete.

1 c. y. concrete requires (27.0÷17.48) 7.6= 11.7 c f. sand.

15.2 c.f. stone produces 17.48 c.f. concrete.

1 cu. yd. concrete requires (27.0÷17.48) 15.2 = 23.4 c.f. stone.

1000 cu. yds. concrete require 1000x1.54 = 1540 bl. cement.

1000 cu. yds. concrete require 1000x11.70 = 11700 c.f. sand.

1000 cu. yds. concrete require 1000x23.4 = 23400 cf. stone.

Total material required for 1000 cu. yds. concrete 1540 bbls. cement, 433 3 cu. yds. sand, 866.6 cu. yds. stone.

RECORD OF TEST CUBES.

Cube No. .....
Where taken .....
Date .....
Time of day.....
Mixer .....
Cement .....
Remarks .....
Cube taken by.....
Signature.
Where stored .....
Date of test.....
Strength of cubes in tons.....
Strength per sq. in. in pounds.....
Remarks .....